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AUTHOR Schulke, Ruthann; And Others
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ABSTRACT

This report documents a study that examines the first 4 years of a beginning chemistry teacher's career. The report explores the difficulties that are faced by the new teacher as she attempted to transform her formal knowledge of chemistry and pedagogy into the practical application of a high school chemistry teacher. The report includes the teacher's difficulties in gaining control of the classroom; in organizing, planning and conducting lessons; and, in dealing with the constraints that were placed on her by school officials, peers, and the expectations of students and parents. The report examines curricular expectations in high school chemistry including the dominance of the text and tests, the mixed signals from peers and administrators that beginning teachers must clarify, and the sources of support that are available to assist new teachers in the early stages of their professional development. The study examines growth in a new teacher's knowledge of content, pedagogy and "pedagogical content" during a four year period, as seen through her own eyes, those of her mentor and those of a university researcher. Sections include: (1) "Introduction"; (2) "A Colleague's View of the New Teacher"; (3) "A Retrospective Personal Report of the New Teacher"; and (4) "Conclusions and Implications". (KR)

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A CASE STUDY OF A NEW CHEMISTRY TEACHER: SOME REASONS UNDERLYING A CLASSROOM TEACHER'S ACTIONS

Ruthann Schulke
Thomas Yocum
James J. Gallagher
Michigan State University

National Association for Research in Science Teaching
Fontana, WI
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INTRODUCTION

This paper will outline a case study of some of the most significant problems faced by a beginning chemistry teacher as she moved through the transition from student to teacher. This case study is unique because it includes the viewpoint of the beginning teacher as a researcher. This study is presented from three perspectives: the new chemistry teacher, the new teacher's 'helping teacher' and a university researcher. The perspective of the university researcher was useful in explicating the two points of view concerning this transition that will be presented: that of the 'helping teacher' assigned to assist the new teacher in her adjustments to her new position and that of the new teacher herself. It is believed that these viewpoints will allow the development of a perspective that could benefit future research efforts focused on improving the transitions of science majors, especially chemistry majors, into science teachers.

The transformation from college student to science teacher is an internal process and can be viewed as the development of the meta-cognitive skills of the science teacher blended with an increased sensitivity to the needs and concerns of the students. From the perspective of the 'helping teacher' the transition of a beginning teacher is seen from the outside and this view might be considered as

limited. However, an outside perspective can have merit as it adds to the total picture of the factors influencing the transformation.

One of the difficulties faced by all teachers is the intensity of the workload. This is especially difficult for the beginning teacher who must plan lessons and express their understanding of the subject matter for the first time. During her first year of teaching Ruthann taught six classes per day. This was required of all teachers in our school during the first two years of Ruthann's teaching career. Her initial assignment included three pre-algebra, one geometry, and two chemistry classes. Thus, she was burdened with preparation for classes in three different subject areas and several different levels of students. The prep or planning period was placed at the end of a very busy day. Additionally, she was the Pompon squad advisor, a responsibility that required attendance at afternoon practices and evening games during the basketball and football seasons. This job also extended to spring tryouts and summer camps.

In her second year, Ruthann taught one life science and five chemistry classes and advised the Pompon squad. During the third year, when the school could require only five classes for teaching assignments, Ruthann volunteered to teach six classes, one general science and five chemistry classes, and continued as the Pompon squad advisor.

Teaching an additional class gave Ruthann additional pay at a time when she was at the bottom of the pay scale. Finally, in year four, Ruthann taught six chemistry classes (again on a voluntary basis which allowed her to have only one preparation), was National Honor Society advisor, served on the school improvement committee and participated in a seminar in physical science. These heevy assignments in Ruthann's first four years placed a heavy burden on her, in terms of number of students per day, time commitments beyond the teaching day and total workload.

Tom's assignment as Science Department Chairperson required him to submit purchase orders for the department, inventory supplies, generally coordinate shared equipment for the department and serve as liaison to the administration. Tom taught six classes per day during Ruthann's first two years and had no release time for serving as a "helping teacher." A helping teacher in our high school is a volunteer who assists a new teacher with any questions or concerns that might arise in the first three years. From the vantage point as Ruthann's helping teacher, Tom recognized part of the transition of any new teacher to include learning procedures, becoming familiar with the working school environment and meeting the people involved - the students, administrators, parents, and colleagues. This "learning the turf" would be expected in any new job. For teachers there is an additional part of

this transition that focuses on the development of content knowledge, pedagogy and the blending of both of these in classroom practice (Shulman, 1986).

The literature concerning the problems faced by new teachers in general is quite extensive and much of this research can be expected to apply to new science teachers. The literature concerning new science teachers, particularly chemistry teachers, is much more limited (Sanford, 1988). There appears to be an additional burden placed on new chemistry teachers that must be explored in depth. The subject matter of chemistry is largely abstract by reason of magnitude of the objects conceptualized. Molecules and atoms are much too small to be seen and therefore difficult for students to conceptualize. This abstract quality of its content makes chemistry more difficult to plan and teach effectively.

A COLLEAGUE'S VIEW OF THE NEW TEACHER

With this general background set, I will sketch several of the significant external factors that influenced Ruthann's transition to chemistry teaching. The very first factor was Ruthann's office desk. Before school started her first year, I was determined to have Ruthann be considered a science teacher despite the fact science was not her major assignment. I asked to have Ruthann's desk placed in the science office in order to have her be considered a science colleague. At the time I did not know whether such a simple

strategy would be of any real value but I felt it was necessary to try it. Since I was also teaching six classes per day and was unable to observe Ruthann in the classroom, I felt this desk placement might afford an important contact between Ruthann and the other science teachers, including me. I only recently learned that Ruth did consider this first step toward inclusion in the department to be of importance to her. The desk placement came at a time when she was questioning whether she would become a math or chemistry teacher in our high school and placing her desk in the science office gave her some slight security in believing that she would become a full-time science teacher.

The second factor that represented a critical episode in Ruthann's development, which became visible to me, occurred very early in her first year during one of the initial meetings of Ruthann, the principal and me. I attended most meetings between Ruthann and administrators in my unofficial position of 'helping teacher.' At this particular meeting the principal wanted to discuss Ruthann's lesson planning. He inquired about her daily plans for the upcoming week and, after satisfying himself that they were well-prepared, asked to see her plans for the remainder of the year. When Ruthann stated that they were not yet complete the principal made an appointment, for approximately one month later, at which time he would request Ruthann's lesson plans for the entire year.

As we left the meeting Ruthann was distraught. She was quite certain that she could not be prepared for the next meeting in a month, with lesson plans for the remainder of the year. She had left with the impression that the principal was demanding that she have daily, detailed plans for the remainder of the school year for all three subjects she was teaching that year. Since Ruthann was attempting to practice concept mapping as she planned each unit she became quite concerned about the short time allowed for creating plans for the remainder of the year. Having worked with the principal for seven years, I knew that this was not the expectation of the principal. He wanted to see the general outline or plans that would determine the scope or the material that Ruthann would teach in each subject. More detailed plans would be expected perhaps one month beyond the date of the next appointment. When I was able to convey this information to Ruthann, it relieved her and allowed her to focus on the planning that was expected of her.

Ruthann's lesson planning now changed. She found that she did not have adequate time in her hectic schedule to create concept maps and the types of plans that allow for conceptual change teaching practices in three different courses. She stopped trying to plan each class minute by minute and opted for more generalized plans. At this time I began to convince Ruthann that it was not possible to scrutinize up to one hundred and sixty papers each night and

plan a lesson afterwards. She was physically unable to teach with less than eight hours sleep each night. Time management became her greatest concern.

The next factor that I could see seriously impacting Ruthann's teaching was the laboratory work. In addition to planning which laboratory work will best aid the conceptualizing that the students will undergo, Ruthann, as does each chemistry teacher, had a host of questions to face. What materials are on hand? Where are they? Where is the necessary equipment? What substitutions can be made? How can I best create a safe lab atmosphere? How can I deal with students who, perhaps unintentionally, threaten the safety of others? What time must be allowed for completion of this work? Which lab activities will best mesh the concepts we are discussing with the students' present concepts? These are but a sample of the many laboratory questions that new chemistry teachers must struggle to answer.

Ruthann was able to receive information from the preceding chemistry teacher, Mark, between classes and before and after school. These 'discussions' were often quick and superficial due to the hectic nature of both Mark and Ruthann's schedules. There was no time set aside for an in-depth discussion of why things should, or could, be done in a particular manner.

I believe chemistry teachers face greater demands in regard to planning for safety than other science teachers. Since I was not in a position to monitor Ruthann's lab, I suggested that she try to utilize the types of labs that she felt confident with and that she try to minimize her efforts to create new experiments or modifications of the text activities until she had more time to test the lab work. This seemed to help Ruthann survive her first years of chemistry teaching. I also encouraged Ruthann to adopt those lab activities that either I, or the previous chemistry teacher, had found useful.

The unique position of lab activities in science instruction has been long noted and proper lab instruction has been studied (Tamir, 1989). Ruthann did not have time to do the proper laboratory planning while she was developing her classroom management skills and learning to apply her theoretical chemistry knowledge to the high school classroom.

One final factor that I noted in Ruthann's first year occurred in the spring as the prospect of final examinations loomed in front of her. Ruthann came to me inquiring about the length of exam periods and what type of exam she would be expected to give to her classes. As we talked about exams, Ruthann became quite concerned that she might be expected to create a final exam on her own in a relatively short period. I decided that we should look at all the options available to her.

Since Ruthann was using the same scope, sequence and text as the previous chemistry teacher, I suggested that she might simply use the exam from the previous year. That particular exam consisted of a portion of one of the ACS general chemistry exams and a set of additional items written by the previous chemistry teacher. Ruthann looked at this exam and determined that it might not be entirely appropriate for her classes. I suggested that she use the first half of the ACS exam and add items that she felt would be more appropriate than the items used by her predecessor. She agreed to this and proceeded to write her exam items.

The following year Ruthann came to me with her exam results and expressed some concerns with the overall test scores, as well as the results of particular items on the exam. I suggested that I could analyze the results of the ACS portion of the exam to determine which items merited scrutiny. Ruthann felt this was a good idea and gave me the ACS answer sheets. By the end of the second year, Ruthann agreed to have me analyze the ACS exam results again and make comments to her concerning a comparison of the exams of the first two years.

I extended my analysis to include information about the academic achievement levels of the students in each exam group to determine if one group showed greater academic ability as measured by standardized test scores. I also summarized some of the types of activities and time spent

per unit outlined in Ruthann's plan books and correlated them to the average score for each item each year. I then supplied the results of this comparison to Ruthann. This past year Ruthann came to me suggesting that she was now ready to use only those ACS exam items that were pertinent to her teaching, along with items she had been developing over the last two years.

A few closing comments from my viewpoint are in order. As Ruthann moved into her teaching assignment her first year, I was eager to assist her and lend whatever help and advice I could. I was in my sixteenth year of science teaching and had taught chemistry for three years. I had already begun a graduate program leading toward a specialist degree in science curriculum and instruction. I had a wealth of information and ideas that I felt would serve both of us well as we proceeded through the school year. What naivete!

Scheduling impeded most efforts to observe Ruthann in the classroom and laboratory. I had no class period free to work with Ruthann. At the end of the day, when we might be expected to meet and discuss concerns or plan together, one or both of us would have commitments, such as meetings or extra-curricular duties that precluded our working together. We were forced to meet and work together at any opportunity we could find. Before school, at lunch in the science office or during the infrequent school assemblies proved to

be the best opportunities to get together. Without frequent discussions with Ruthann, I was not able to discern adequately the questions, conflicts and frustrations that were assailing Ruthann as she worked toward improving the quality of her teaching. It was only during the past year, when I did have a planning period that afforded me the opportunity to enter Ruthann's classroom, that I was able to see the confident, exemplary chemistry teacher that she has become (Garnett & Tobin, 1988; Tobin & Fraser, 1990).

NOTE: As readers examine the following section, it is important to recognize that Ruthann is, by all standards, a well-prepared teacher of chemistry. She has a major in chemistry with appropriate background in mathematics and physics. She also studied pedagogy and completed a term of practice teaching. Most people would agree that she received a good background in teacher preparation. What follows is a report of difficulties she faced with her knowledge of the fields of chemistry and pedagogy.

A RETROSPECTIVE PERSONAL REPORT OF THE NEW TEACHER

Revelations at the Chalkboard: A New Understanding of Chemistry Content

So many times in the last couple of years I have been writing at the chalkboard trying to explain a concept when suddenly I get this strange feeling--a knot in my stomach and sweaty palms--and then a click and I realize I have just understood what the concept <u>really</u> means. (Although I found it hard, I managed to stifle the "Oh, I get it!")

It was not until I began teaching chemistry that I really began to understand some concepts and how they are related. Some of the misconceptions I had simply involved my understanding of definitions. For example, I finally realized that density is how much a specified volume of a substance weighs, not just D = m/v. For example, you can weigh 1 mL of water to see that it has a mass of 1.0 gram. Another example is the difference between a law and a theory. In my undergraduate studies, I learned that a law is only an observation and a theory is an explanation of that observation. An example that helped me to understand this difference is that of a balloon in a refrigerator. The observation that it shrinks when you put it at a lower temperature is a law while the explanation of why it shrinks is a theory.

There are several major areas where my thinking of chemistry has made even greater progress. These areas include the relationships between temperature and pressure, the difference between heat and temperature, the importance of charges, the similarities and differences between types of bonding and, finally, the relationships found in the Periodic Table.

One of the first topics I teach in the course of a year is that of heat and temperature. Although I studied physics in both high school and college, I never understood that heat was dependent upon mass and change in temperature while temperature is not. Once I clarified my understanding of these points, I was able to better understand that

temperature is the average kinetic energy of molecules while heat is total kinetic energy and that temperature is directly related to the velocity of the particles. An example that helped me understand this is the comparison of temperature and heat of a cool tub of water to a hot cup of water. I now know that heat is a quantity of energy while temperature is measure of its "hotness."

A theme I have found to be important in teaching chemistry is the importance of charge. It seems almost everything that occurs is due to force of attraction between unlike charge or the force of repulsion between like charges. This explains much of the unusual behavior of water, the reason substances exist in a particular phase at room temperature, and why water and other polar substances dissolve ionic compounds. This also explains hydrogen bonding, ionic bonding and why electrons are held to an atom.

This introduces the next area that I now comprehend better--that of bonding. I used to believe that ionic and covalent bonding were two completely different types of bonding but now I see that they are just the extremes on the ends of a spectrum where nonpolar covalent bonding is equal sharing of electrons, polar bonding different degrees of unequal sharing and, finally, ionic bonding where electrons are shared so unequally that the electron has been transferred. I also see metallic bonding as a blend of both covalent and ionic bonding.

My final topic is that of the periodic table. I knew the periodic trends and could recite them but I could not explain what they meant or how to use them. Now, I understand that the similarities in valence shells can be used to predict chemical behavior and to find a reasonable replacement for a reagent in a lab experiment.

In thinking about the changes that have taken place in my understanding of chemistry I have noticed some important transformations that have occurred in my thoughts about both learning and teaching. First, although I was a good chemistry student with a high grade point average, much of my understanding in the field of my major was very superficial. This was especially true regarding my knowledge of some of the basic ideas and concepts. Much of what I knew I 'glossed over,' memorizing for tests without really understanding. This was possible because of the large classes in chemistry and the superficial, fact-based testing.

The revelations that I had while planning and teaching have led me to a better understanding of chemistry and of how to teach it to my students for understanding. I have also noticed that these improvements in my thinking have, at times, been triggered by a student's question or some other problem that was difficult to answer. These situations caused me to rethink the meaning of a particular concept so that I could properly respond to the student's question. This has changed the way I teach because I have observed how I learn. I now use more examples, tie concepts together and

question my students more. Thus, my experience in attempting to teach has helped me reformulate my knowledge of subject matter and, in turn, has caused me to reformulate and refine my methods of teaching. I insist that students connect new material to old material so they do not retain loose fragments of information, for they are useless fragments until they are connected in meaningful ways.

I have realized that learning takes more than memorization. So often we memorize definitions and recite them on tests without truly understanding what they mean or why they happen. I believe this is because we, as students, are seldom asked to give these type of explanations. Now, as I study and listen to new material, I find myself asking these questions. Also, I now compare concepts to each other finding their differences and similarities so that I can connect new concepts to old ones. In doing this, I try to think of both an appropriate example and nonexample to aide in my understanding of the concept.

> "Good teachers are always in transition, always moving back and forth from teacher to student. To teach, after all, is to learn."(Anonymous,1990).

As the above quote states, I am continually flipping from teacher to student and back. As I do so my teaching strategies change and therefore, I believe I become a better teacher. I now recognize that I must relate one chapter of material to the next if I want to get my students to learn rather than memorize. For example, when we study electron configurations I make a point of discussing how the elements

in the same family have the same valence shell configuration. Once we get to the chapter on Periodic trends I bring this up again and we use it to discuss family behavior. Because of this, I believe it is important to know what concepts I will be teaching later in the course so that I can stress the importance of related concepts that are introduced earlier in the year. Continually reviewing concepts as they recur strengthens the students understanding of old concepts and demonstrates the connectedness of the material.

The transition from student to teacher is a tough one, but the one from student to science teacher is even tougher.

> "Compared to teachers in other secondary school content areas, beginning science teachers face extremely complex challenges in planning and teaching..." (Sanford, 1988).

As a student you do not see the "behind the scenes" preparation of a science teacher so there is no example to follow. Also, the time period allotted for student teaching does not allow for the student teacher to familiarize herself with the procedures encountered during the entire school year. For example, the creation of a syllabus, midterm and final exams, filling out of report cards, and parent-teacher conferences are not all addressed in a single semester of student teaching. This makes it difficult for a new teacher to approach these tasks with any amount of accuracy and confidence. Therefore, this reduces the time that a science teacher can spend on preparing the quality demonstrations and experiments that are so important to teaching the concepts.

On the first day of my first year of teaching, the principal suggested we handout our course syllabus the first day of class (the next day). I remember thinking "How do I get started? What am I going to teach them? How fast am I supposed to go? Do I have to cover all thirty-one chapters? What kind of class rules should I have?"

In thinking about laboratory experiments, I had similar thoughts. What materials are needed? Do we have them? What would be a good replacement if we don't? Does the lab really work? and, most importantly, How do I tie this into the material we are learning? Because of these questions and the lack of answers to them, I completed very few labs and demonstrations the first couple of years of my teaching.

Through trial and error and a great deal of discussion with my colleagues, I have come to believe that it is important to connect concepts together using demonstrations and laboratory experiments both as a way to introduce and to reinforce concepts. I do believe, however, that explanations must accompany these activities. The material we teach is abstract and difficult but it can be taught for understanding. I also believe that in the battle of quality versus quantity, quality is my goal. If I can get my students to understand the basics of chemistry, teach them how to think about chemistry, and get them excited about it, then I have been successful as a chemistry teacher.

In the sciences, I believe we have what Lee Shulman calls "pedagogical content knowledge". Because of the abstract nature of the content, we must teach it in a special way. I attempt to make the concepts as visible as I can whenever possible through demonstrations and laboratory experiments. It is through such tangible references that students can grasp the abstract concepts of chemistry.

In testing my students I test for understanding by asking open-ended, as well as multiple choice, questions. I believe this decreases the amount of memorization and increases their understanding of the concepts. They must be able to provide examples that fit definitions rather than just the definitions themselves. They must be able to explain concepts and compare them to others. Also, I quiz my students on small portions of material so that they learn to study throughout each chapter rather than just the day before a test.

In the past four years I have struggled to learn the concepts in chemistry and how to teach them so that they are understood by my students. I knew teaching would not be easy, but I never thought that any job could be this difficult. I honestly do not believe that I am an exceptional case. The frustration I have experienced has caused me to think long about remaining a teacher. However, the successes I feel each new year have led me to believe that I am in the profession in which I belong.

Each year I teach chemistry differently--better than the year before. I teach it with a better understanding of the content and the students. Now I include appropriate experiments and demonstrations more frequently. Now, teaching chemistry is not as hard, it is merely a challenge that I have decided to accept.

> "...there is a growing awareness that university study of an academic discipline may not provide the kind of knowledge and understanding that teachers need to effectively transform their academic knowledge into instructional activities in the classroom." (Sanford, 1988)

I support the above statement and, therefore, the following changes in science teacher education so that upcoming chemistry teachers do not have to face becoming a teacher in the manner I did. Many times I thought "I'm not doing this right so why should I continue to masquerade as a teacher?"

> "Working conditions such as teaching schedules, number of preparations and room assignments are frequently worse for beginning teachers than for their more experienced colleagues." (Sanford, 1988)

First, I believe that we must arrange to eliminate the above scenario. New science teachers should be given a lighter load so that the rest of their day could be spent with a mentor teacher thinking about what had happened in the areas of classroom management, content and daily preparation. I feel this would have been extremely helpful

in guiding me to become an effective teacher. I could have asked the questions that were on my mind and I would have had the time to really think about what I was doing and why.

Second, I feel I was required to take enough undergraduate chemistry courses to properly prepare me for teaching but I lacked the opportunity to discuss the presentation of specific topics in chemistry. I would have benefited from a course where each prospective teacher had to present a chapter and then discuss the problems they had with the material and its presentation. Also, discussion of appropriate labs for each chapter and decisions about the sequence of presentation as well as discussions on textbook arrangement and safety, disposal, and storage of chemicals would have been extremely beneficial.

Finally, I feel teacher education should increase the number of contact hours a prospective teacher has with students of the age they will be teaching. I believe that I should have had the opportunity to observe science teachers and to discuss science teaching with them throughout my teacher education program.

CONCLUSIONS AND IMPLICATIONS

This case study has shown what has happened to a new high school chemistry teacher and proves that "the professional development of beginning teachers deserves more attention from the science education community."(Sanford, 1988). The process of transition of this teacher during the

first four years has been described. While each new chemistry teacher faces a unique situation in which they must move from college student to classroom teacher, we believe this case is sufficiently broad enough to raise issues in science education for the 1990's.

The concern of the 1980's in science education has produced great strides in pre-service education, curriculum design and instruction based on developments in cognitive psychology. As yet there has been little done in the development of mentoring for the emerging secondary science teachers who, at present, must begin their teaching careers in rather significant isolation, much as Ruthann did four years ago. There is little in the way of systematic support for new teachers at a time when the need seems greatest.

The literature of science education indicates that science teachers must have sound content knowledge in the subject(s) they are to teach, classroom management skills and a knowledge of the proper instructional strategies based on the cognitive development of student concepts (Duschl & Wright, 1989; Hewson & Hewson, 1988). Recent research also indicates a need for science teachers to possess a stronger background in philosophy of science and its implications for instruction (Cleminson, 1990; Gallagher, 1990). As we learn more about the elements comprising good science instruction, we place greater burdens on those entering the teaching profession. We must allow sufficient time for these new

teachers to blend these elements into the sound pedagogical content knowledge of an exemplary science teacher. As this case study has shown, a severe workload magnifies problems of time management for the beginning chemistry teacher. We need to find ways to decrease the workload of beginning science teachers.

Researchers should begin to examine in greater detail the means by which the theoretical knowledge of the content and pedagogy of the pre-service teacher develops into the practical classroom instruction of the exemplary science teacher. This transition occurs over a span of several years. It requires a commitment from university researchers, experienced classroom teachers and the new teachers themselves. Once such a research base is built the science education community can provide information to guide the practices of the nation's secondary schools. Only a broad research base can be expected to move the public secondary schools from the present usual practice of leaving new science teachers to develop in relative isolation as best they can.

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REFERENCES

Anonymous. (1990). From student to teacher. Teacher Magazine, 1 (7), 33.

Cleminson, Andrew. (1990). Establishing an epistemological base for science teaching in the light of contemporary notions of the nature of science and of how children learn science. Journal of Research in Science Teaching, 27, 429-445.

Duschl, Richard A., and Wright, Emmett. (1989). A case study of high school teachers' decision making models for planning and teaching science. Journal of Research in Science Teaching, 26, 467-501.

Gallagher, James J., and Tobin, Kenneth. (1987). Teacher management and student engagement in high school science. Science Education, 71, 535-555.

Gallagher, James J. (1990). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. In press.

Garnett, Patrick J., and Tobin, Kenneth. (1988). Teaching for understanding: Exemplary practice in high school chemistry. Journal of Research in Science Teaching, 26, 1-14.

Hewson, Peter W., and Hewson, Mariana G. A'B. (1988). An appropriate conception of teaching science: A view from studies of learning. Science Education, 72, 597-614.

Sanford, Julie P. (1988). Learning on the job: Conditions for professional development of beginning science teachers. Science Education, 72, 615-624.

Shulman, Lee S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15, 4-14.

Tamir, Pinchas. (1989). Training teachers to teach effectively in the laboratory. Science Education, 73, 59-69.

Tobin, Kenneth, and Fraser, Barry J. (1990). What does it mean to be an exemplary science teacher? Journal of Research in Science Teaching, 27, 3-25.